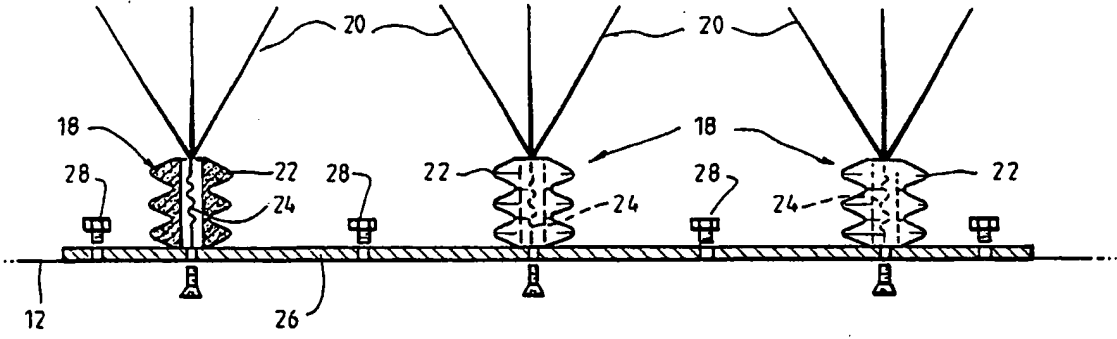




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/AU94/00040 <b>(22) International Filing Date:</b> 31 January 1994 (31.01.94) <b>(30) Priority Data:</b> PL 7030 29 January 1993 (29.01.93) AU <b>(71) Applicant (for all designated States except US):</b> INTERNATIONAL PROTECTION CONSULTANTS PTY LTD [AU/AU]; Technopark, Dowsings Point, Hobart, TAS 7001 (AU). <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> GUMLEY, John, Richard [AU/AU]; Technopark, Dowsings Point, Hobart, TAS 7001 (AU). GUMLEY, Stephen, John [AU/AU]; Technopark, Dowsings Point, Hobart, TAS 7001 (AU). <b>(74) Agent:</b> CARTER SMITH & BEADLE; Qantas House, 2 Railway Parade, Camberwell, VIC 3124 (AU).		<b>(81) Designated States:</b> AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, KZ, LK, LU, LV, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SK, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> With international search report.
<b>(54) Title:</b> IMPROVEMENTS IN LIGHTNING PROTECTION   <b>(57) Abstract</b> <p>A lightning protection system comprises an Early Streamer Emission (ESE) air terminal (14) and a plurality of Delayed Streamer Emission (DSE) element (18) strategically spaced around said ESE whereby the protective radius of said ESE terminal is extended and lightning is directed to said ESE. A DSE element (18) has a plurality of upwardly diverging finials (20) with pointed tips an insulating body (22) and an internal resistor (24) forming a series impedance between said finials and an earth plate (26) on which a series of DSE elements are mounted to provide a DSE device.</p>		

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**TITLE: IMPROVEMENTS IN LIGHTNING PROTECTION**

This invention relates to improvements in lightning protection, and in particular relates to improvements in the lightning capture efficiency of lightning conductors, or more specifically the air terminal portion of a lightning conductor system.

Benjamin Franklin demonstrated in 1752 that electricity was attracted to sharpened pieces of metal. In 1753 he wrote a detailed description of a lightning conductor comprising sharp pointed rods. In later letters, and after observing the practice of English electricians, he observed that sharp points would create corona to ionize the air in a slow way by bleeding current into the air. However, he also commented that blunt rods may be more efficient in the capture of the lightning stroke.

Since Franklin's time, there have been many inventions to improve the capture ability of the original sharp Franklin rod. These comprise multiple points, radioactive enhancement, battery powered spark generators, wind driven piezo generators and, more recently, multiple point air terminals that create sparks in the presence of the natural electric fields occurring below a thunderstorm. One example of such a multiple terminal is disclosed in United States Patent 4,480,146.

There has been a growing acceptance in science that corona from sharp points actually creates a space charge above the points. Such space charge intervenes between the cloud and earthed point and acts to modify the electric field observed at the point. Through this process, an approaching downward leader, precursor to the main discharge, must approach much closer to the earthed point to trigger an upward intercepting discharge. It is the closing of the air gap between up and down discharges that finally completes the cloud to ground electrical path. This closure creates the lightning strike point.

Recently, there have been two generic concepts to cause an early up discharge from a grounded conductor. Both concepts form the basis of a new technology known as Early Streamer Emission (ESE) terminals.

One ESE terminal uses a pulse format to eliminate the observed pauses in up streamer development. The other, as disclosed in United States Patent 4,760,213 (J.R. Gumley) uses a spherical geometric shape in the presence of electrostatic fields in order to minimize corona. The same device creates triggering impulses across a spark gap on the approach of the precursor down leader. This triggering impulse creates free electrons and photo ionization to aid the development of an upward leader.

An alternative technology seeks to prevent lightning strikes at a particular location by neutralizing the charge differential between a cloud and the location before a 'flashover point' occurs. Such a 'Dissipation system' is disclosed in United States Patent 5,043,527 (R.B. Carpenter).

In the disclosure of United States Patent 5,043,527, there is a multiplicity of corona-producing points, and there is a claim that the electric charge in a thundercloud can be dissipated. The arrangement is designed to retard, in time and in current magnitude, the formation of an up discharge or upward leader, or to prevent the formation thereof, by dissipating the cloud charge before a precursor leader or downleader is able to develop.

A third approach, termed the Delayed Streamer Emission (DSE) concept, assumes that a precursor leader will develop, but seeks to delay a response from the ground.

It is an object of this invention to provide an improved lightning protection system and method.

Accordingly, one broad form of the invention provides a lightning protection system for a structure or location, including an Early Streamer Emission (ESE) air terminal located on said structure or at said location, characterized in that, at least one Delayed Streamer Emission (DSE) element is located on said structure, or at said location, strategically spaced from said ESE terminal whereby the protective radius of said ESE terminal is extended.

A further broad form of the invention provides a method of lightning protection characterized in that, one or more Early Streamer Emission (ESE) air terminals are arranged in strategic combination with a plurality of Delayed Streamer Emission (DSE) elements to protect a structure or location by directing lightning strikes to said ESE terminal or terminals.

A still further broad form of the invention provides a lightning protection system for a structure or location characterized in that, a plurality of passive lightning termination devices with respective positive and negative up-leader time advantage are strategically combined at said structure or location to extend the attractive radius of a primary collector.

A still further form of the invention provides a Delayed Streamer Emission (DSE) element characterized in that, it includes a plurality of upwardly diverging finials providing corona-forming points and a series impedance to inhibit imitation and subsequent propagation of lightning up-leaders.

The invention will now be described in detail hereinafter with reference to the

accompanying drawings, in which:-

Fig. 1 is a diagrammatic view of an arrangement for determining the attractive radius of a conventional Franklin rod on a structure;

Fig. 2 is a diagrammatic view, similar to that of Fig. 1, with an ESE terminal in place of a Franklin rod;

Fig. 3 is a diagrammatic view, similar to that of Figs. 1 and 2, with ESE and DSE terminals in place in accordance with the invention;

Fig. 4 is a side elevation of a DSE array according to an embodiment of the present invention;

Fig. 5 is a perspective view of a DSE element suitable for installation on the parapet of a structure; and

Fig. 6 is a perspective view of an alternative to the element of Fig. 5.

In Fig. 1 there is shown an arrangement determining the attractive radius of a conventional Franklin Rod 10 on a structure 12. One must first decide a level of protection required to produce a spherical surface  $S_1$ , radius  $D$  (striking distance) which represents an initiation distance. This distance is set by the electric charge on the approaching downleader. It is the distance from the head of the downleader to the earth point at the time of launching the upward propagating leader.

This downleader charge is also related to the peak discharge current of the subsequent stroke. The latter has been measured by many researchers and it is now possible to statistically protect against all discharges above a given peak current. For example, 93% of all first stroke discharges exceed 10kA which relates to a leader charge of about 3 Coulombs.

However, drawing a scaled spherical surface  $S_1$  about the Franklin Rod 10 does not guarantee the rod will be struck, even though it may launch and propagate an up-leader. Competition comes through other points on the structure. An equal probability  $L$  locus can be drawn where the Franklin rod and other structural projections have equal probability to launch an up leader. Inside this equal probability locus is the collection volume  $V$  now referred to in Australian Standard AS1768-1991. This provides a radius of protection  $R_p$ , which in Fig. 1 ( $R_{p1}$ ) does not extend to all parts of structure 12, and is therefore inadequate.

In Fig. 2 there is shown the effect of an ESE 14. Here we see the inclusion of the term  $\Delta l$ , which is the distance advantage due to the ESE effect. Under normal

circumstances, a time delay occurs from the time that a critical electrical field strength is achieved to the time of actual launch and propagation of an up-leader. Reducing this time delay can be represented as an increase in initiation distance.  $\Delta l$  is derived from the time advantage of the ESE terminal 14 multiplied by the up-leader propagation velocity to obtain a distance advantage. There is no  $\Delta l$  for natural points on a structure which still retain an initiation distance  $D$ .

The effect of  $\Delta l$  is to increase the radius of the spherical surface to a radius  $S_2$  representing the initiation distance. Noted also is that other structural points are unaltered, making it more adequate. Hence the radius of protection  $R_p$  is increased over that of Fig. 1 (see  $R_{p2}$  in Fig. 2). The effect of an ESE air terminal in the increasing of attractive ability, can clearly be seen in Fig. 2. The collection volume is increased; see IV in Fig. 2.

In Fig. 3, there is shown an arrangement according to the present invention in which the outer structural points 16 may not have an initiation distance  $D$ . The points 16 are designed to create corona and actually act to delay the initiation of an up leader. Specifically the outer structural points 16 are provided with DSE devices which are strategically placed and serve to extend the protected area as will become apparent. In this case the initiation distance of the points 16 will be  $D - \Delta l$ . Fig. 3 shows that such a delay actually enhances the capture ability of the ESE terminal by further increasing the value of  $R_p$ . Thus,  $R_{p3}$  (Fig. 3) is greater than both  $R_{p2}$  (Fig. 2) and  $R_{p1}$  (Fig. 1).

In this invention we use the electrogeometric model to explain the advantage of combining ESE and DSE air terminal effects and reveal the design of an air terminal configuration which will have the DSE characteristic.

A suitable ESE terminal is well described in aforementioned United States Patent 4,760,213 and the disclosure thereof is incorporated herein by cross-reference. In such a terminal the reduction of predischage corona and the presence of a triggering arc contributes to an early launch ability. Such an ability may also be available in other EDE devices.

As stated, the DSE concept is opposed to that disclosed in United States Patent 4,760,213. The aim now is to seek, by design, those structural points which may compete with the ESE terminal and equip such points with devices to retard up-leader generation. Such devices are multipointed metallic systems designed to create a space charge immediately above them. The devices utilized in this invention are not designed to capture

a discharge but simply to retard leader development so that capture priority lies with the ESE terminal. Other types of DSE devices may be used in the system of the invention.

Fig. 4 shows a multiplicity of elements 18 according to the invention which act to delay up-leader initiation and meet the DSE criteria for the system of this invention.

These elements preferably utilize a combination of physical properties. Namely:-

1. A series of sharp points to create an abundance of corona/space charge.
2. An insulating piece to allow insertion of a control impedance.
3. A series impedance which will limit the current available to enter the leader channel and hence retard leader development and propagation.

In Fig. 4 one exemplary multi-point arrangement is shown, which is suitable for long parapets on structures.

Each element 18 consists of three or more finials 20, preferably formed from stainless steel, each having a sharp tip.

Preferred tip separation is about 250mm, with about 250mm separating the tips of adjacent elements 18.

An insulating portion 22, comprising a high glaze ceramic insulator, supports finials 20. An internal resistor 24 is located within insulator 22 to limit up leader propagation current.

An earth plate 26 supports elements 18. The plate 26 is formed from stainless steel, and is adapted to be secured by bolts 28 or other fixing means to a parapet of a structure 12.

The overall length of the assembly of Fig. 4 is preferably about 2m, with a height above plate 26 of about 500mm.

Figs. 5 and 6 show two examples of DSE strips generally according to Fig. 4.

Fig. 5 shows one strip 30 on a parapet 32. Fig. 6 shows another design 34 showing a resistor 24 therein.

The relatively simplistic elements of Figs. 4 to 6 act in the following way. During the presence of a high electric field, the multiplicity of points combine to emit corona current. For example, if the impedance is a series resistor it will not inhibit this action, even though its value may be in the order of 1 megohm. Each point may emit 5 microamps in an electric field of 5kV/m and, if thirty points were attached the total drain would be about 150 microamps. Across one megohm the voltage drop would be a mere 150 volts compared with the 100 megavolts appearing between cloud and ground. Thus

the resistor has negligible effect on corona generation, and the resulting space charge would mask the E field observed due to an approaching down leader. This downleader would then have to approach much closer to cause up leader initiation.

If a down leader did closely approach an element of the assembly it would try to cause an up leader to develop with currents exceeding 10 Amperes. Such an up leader would require an escalating current approaching 100 Amperes to propagate. In the initiation phase, with a requirement of 10 Amperes, a one megohm resistor as the impedance for example would drop 10 megavolts or 10% of the total potential. The effect becomes twofold. Firstly, space charge means that a down leader needs to approach closer to initiate propagation. Secondly, propagation is retarded due to the large voltage drop in the series impedance.

High voltage laboratory experiments confirm that a high source impedance seriously inhibits both initiation and propagation of up leaders. Hence it becomes possible to create a "delay" in up leader initiation with resulting advantage to a close air terminal with Early Streamer Emission capability. Such strips (Figs. 4 to 6) are adapted to be located on all upper outer edges of structures lying outside the protective radius of the ESE terminal such that the radius is extended as has been discussed earlier in this specification.

In this invention the combination of time and propagation properties of existing Early Streamer Emission air terminals is combined with new devices designed for Delayed Streamer Emission. This combination will enhance the attractive ability of the former, and decrease the risk of lightning by-passing the primary attractor and striking distant corners and parapets. An electrogeometric model is also described which will apply the time advantage and disadvantage of the two respective air terminal concepts in a manner which will determine the true protective zone of the complete lightning attraction system.

**CLAIMS:**

1. A lightning protection system for a structure or location, including an Early Streamer Emission (ESE) air terminal located on said structure or at said location, characterized in that, at least one Delayed Streamer Emission (DSE) element is located on said structure, or at said location, strategically spaced from said ESE terminal whereby the protective radius of said ESE terminal is extended.

2. A lightning protection system according to claim 1, characterized in that, a plurality of DSE elements are strategically spaced around an ESE terminal in a manner to encourage lightning strikes occurring in the vicinity of said system to strike said ESE terminal.

3. A lightning protection system according to claim 2, characterized in that, said ESE terminal and said DSE elements are passive devices.

4. A lightning protection system according to claim 3, characterized in that, said DSE elements each comprise a plurality of corona-forming points and a series impedance to inhibit initiation and subsequent propagation of lightning up-leaders, the spacing between the corona-forming points within a DSE element being substantially equal and substantially equal to the spacing between adjacent points of adjacent elements.

5. A lightning protection system according to claim 4, characterized in that, said DSE elements are mounted in spaced relationship on an elongate base strip or angle strip for attachment to a parapet of a building to be protected, said base strip forming an earth plate.

6. A method of lightning protection characterized in that, one or more Early Streamer Emission (ESE) air terminals are arranged in strategic combination with a plurality of Delayed Streamer Emission (DSE) elements to protect a structure or location by directing lightning strikes to said ESE terminal or terminals.

7. A lightning protection system for a structure or location characterized in that, a plurality of passive lightning termination devices with respective positive and negative up-leader time advantage are strategically combined at said structure or location to extend the attractive radius of a primary collector.

8. A Delayed Streamer Emission (DSE) element characterized in that, it includes a plurality of upwardly diverging finials providing corona-forming points and a series impedance to inhibit initiation and subsequent propagation of lightning up-leaders.

9. A DSE element according to claim 8 characterized in that, said finials have a sharp tip at their upper end, the tips are substantially equally spaced from each other and are mounted on an insulator within which said series impedance is accommodated and connected to said finials.

10. A DSE device comprising a series of DSE elements according to claim 9, characterized in that, said series of elements are fixed at spaced intervals onto an elongate earth plate whereby the series impedance of each element is electrically connected to said earth plate and the spacing between the tip of adjacent finials of adjacent elements is substantially equal to the spacing between adjacent tips of each element.

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FIG. 1.

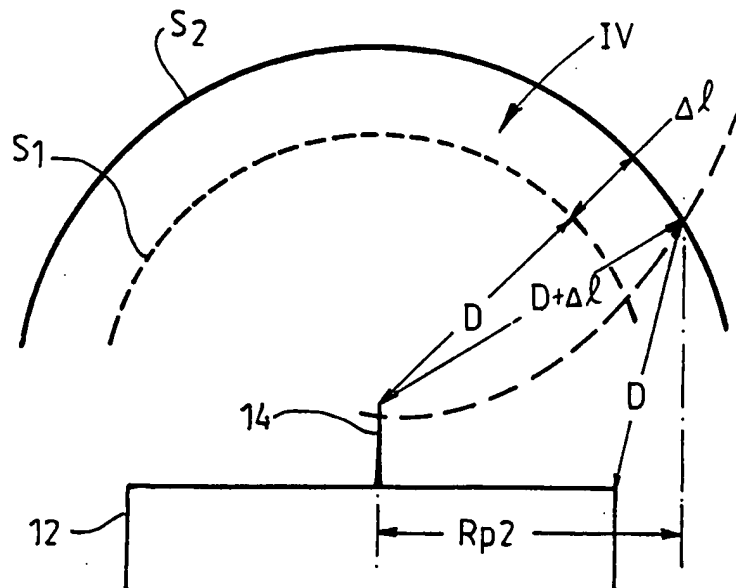
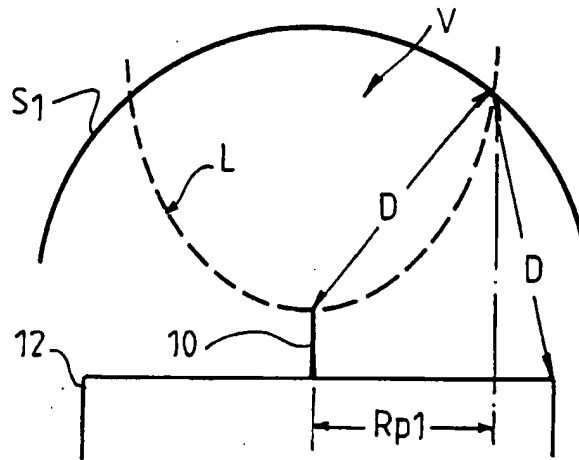
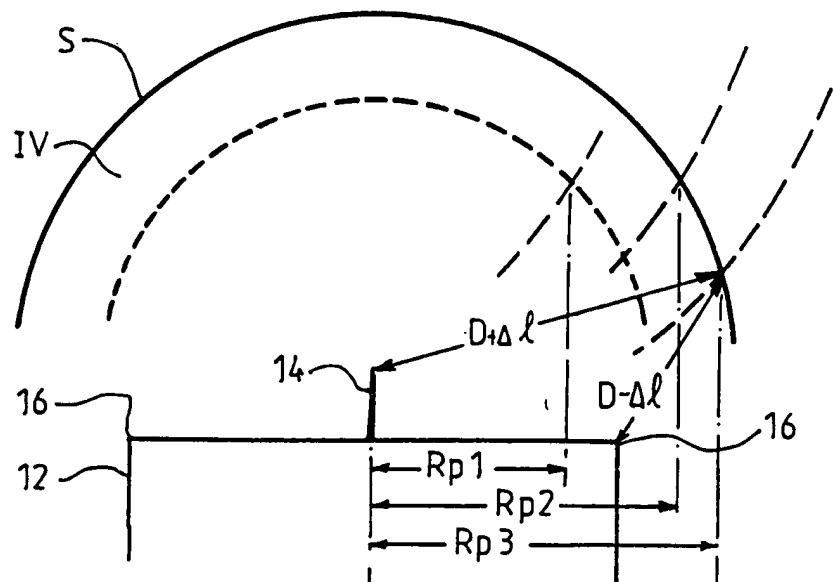
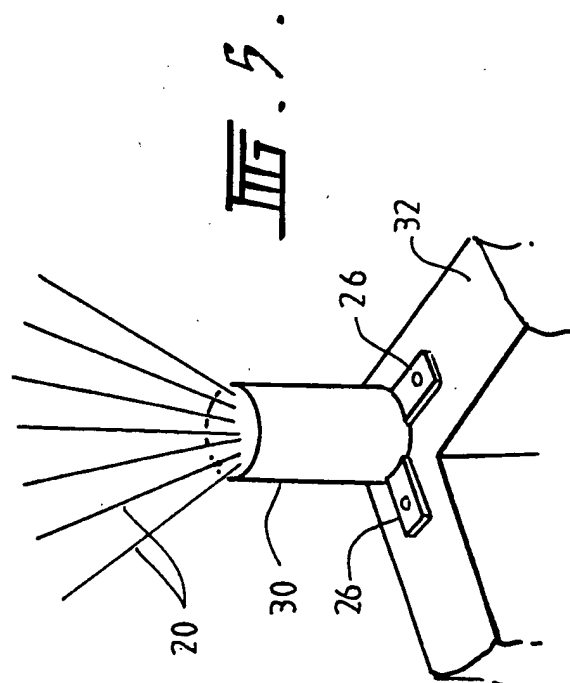
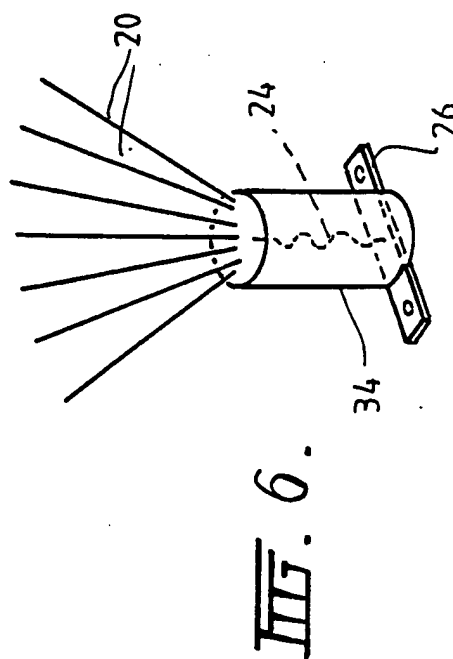
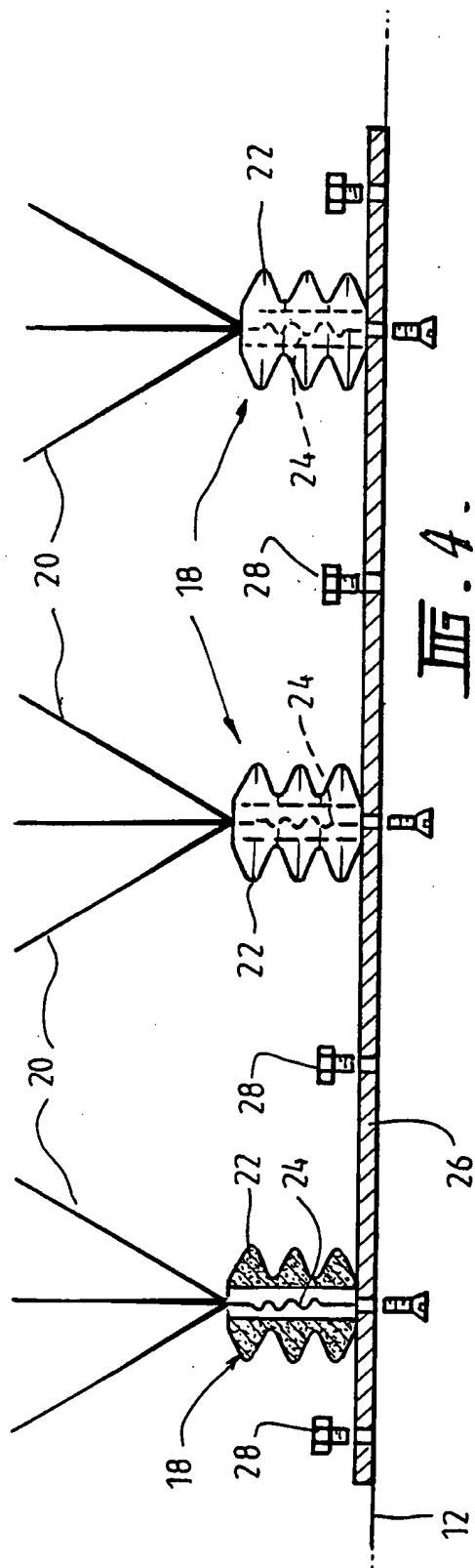


FIG. 2.

FIG. 3.



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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU 94/00040

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> Int. Cl. <sup>5</sup> H02G 13/00  According to International Patent Classification (IPC) or to both national classification and IPC					
<b>B. FIELDS SEARCHED</b>  Minimum documentation searched (classification system followed by classification symbols) IPC : H02G 13/00, H05F 3/04, H01T 19/04  Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched AU : IPC as above  Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)					
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>					
<b>Category*</b>	<b>Citation of document, with indication, where appropriate, of the relevant passages</b>	<b>Relevant to Claim No.</b>			
X,Y	Derwent Abstract Accession No. 84-131873/21, Class W06, SU,A, 1035841 (BERTYN V R) 15 August 1983 (15.08.83) Whole Abstract	8,9			
X	GB,A, 2058477 (DAYTON-GRANGER INC) 8 April 1981 (08.04.81) Figs 2,3, Page 2 lines 1-29	8,9			
Y	EP,A, 158150 (I.S.P.E. S.a.s. di ERMINIO GIANA eC.) 16 October 1985 (16.10.85) Fig 1, Page 4 lines 19-25	8,9			
<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="display: flex; align-items: center;"> <input type="checkbox"/> Further documents are listed in the continuation of Box C.         </div> <div style="display: flex; align-items: center;"> <input checked="" type="checkbox"/> See patent family annex.         </div> </div>					
<table style="width: 100%; border: none;"> <tr> <td style="width: 33%; vertical-align: top;">           * Special categories of cited documents :            "A" document defining the general state of the art which is not considered to be of particular relevance            "E" earlier document but published on or after the international filing date            "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)            "O" document referring to an oral disclosure, use, exhibition or other means            "P" document published prior to the international filing date but later than the priority date claimed         </td> <td style="width: 33%; vertical-align: top;">           "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention            "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone            "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art            "&amp;" document member of the same patent family         </td> <td style="width: 33%;"></td> </tr> </table>			* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
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Date of the actual completion of the international search 6 May 1994 (06.05.94)		Date of mailing of the international search report 11 May 1994 (11.05.94)			
Name and mailing address of the ISA/AU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA  Facsimile No. 06 2853929		Authorized officer <div style="text-align: center; margin-top: 20px;">   <b>P.F. GOTHAM</b>          Telephone No. (06) 2832165       </div>			

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No.  
**PCT/AU 94/00040**

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member	
GB	2058477	FR	2463567
EP	158150	AT 77515 JP 60225400	DE 3586214 ZA 8502049
		IT	1210093
END OF ANNEX			